International Journal Of advance research in Science and Engineering http://www.ijarse.com
(IJARSE) 2012, Vol. No.1, Issue No. I, September ISSN-2319-8354

"WIND / DIESEL HYBRID ENERGY SYSTEM FOR A CELLULAR MOBILE TELECOMMUNICATION BASE STATION"

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Abstract

This paper gives the design idea of optimized Wind/Diesel Hybrid Energy System for cellular mobile telecommunication base station over conventional diesel generator for a particular site in central India (Bhopal). For this hybrid system, the meteorological data for one year of hourly wind speed, are taken from Bhopal (Longitude 77^o.35'and Latitude 23^o.28') and the pattern of load consumption of mobile base station are studied and suitably modeled for optimization of the hybrid energy system using HOMER software. The simulation and optimization result gives the best optimized sizing of a wind energy system with diesel generator back up for a particular mobile telecommunication base station. The performance of this system seems more cost effective in terms of its net present costs (NPC) and environmental friendly over the conventional diesel generator like reduced the emission of CO_2 and other harmful gasses in environments. This system will be more cost effective in the long run with minimal maintenance requirements and preferred, since it is more environmental friendly with 81% uses of renewable energy (wind energy), over the use of a diesel generator backup which is found to produce only about 19% electricity contribution in adverse climatic conditions. It is expected that the newly developed and installed system will provide very good opportunities for telecom sector in near future.

Keywords: *Hybrid energy systems, Mobile telecommunication base station, Wind turbine, Diesel generator, Optimization.*

1. Introduction:

Obtaining reliable and cost effective power solutions for the worldwide expansion of telecommunications into rural and remote areas presents a very challenging problem. Grids are either not available or their extensions can be extremely costly in remote area. Although initial costs are low, powering these sites with generators require significant maintenance, high fuel consumption and delivery costs due to hike in fuel prices. Wind power is expected to be economically attractive when the wind speed of the proposed site is considerable for electrical generation and electric energy is not easily from the grid [1]. This situation is usually found on island and in remote localities. Nevertheless, wind power is intermittent due to worst case weather conditions such as an extended period of overcast skies or when there is no wind for several weeks. As a result, wind power generation is variable and predictable. To solve this problem, the hybrid wind power with diesel generation has been suggested [2-3]. A hybrid wind diesel is very reliable because the diesel acts as a cushion to take care of variation in wind speed and would always maintain an average power equal to the set point. The ability to generate electricity is a building block of modern societies. The utilization of wind turbines to produce electricity has been practiced for over one hundred years; similarly, diesel engines have been a method of producing electricity since the 1940s [1]. However, the field of engineering concerned with the coupling of wind power and diesel generators has essentially just begun. With increasing introduction of wind generators in wind-diesel systems, system stability is becoming a crucial issue to the power company. Due to the intermittent characteristics of wind energy the most difficult issue is to assess the capacity adequacy of the hybrid system in addressing the electricity demand of the consumers. However, the well developed techniques applied to conventional generation system reliability evaluation, associate fixed capacity outputs to generating units and cannot be readily extended to include wind energy sources that have highly fluctuating capacity levels [4]. A number of authors reported a variety of models to deal with this issue. All these models can be roughly classified by their techniques into two categories: the Monte Carlo Simulation and the analytical method. The application of the Monte Carlo Simulation to wind energy generation system utilizes prediction techniques to obtain time series wind speed data and integrate this fluctuant attribute with generation unit random failures to obtain system generating capacity adequacy indices [4, 5, 6, 7]. In this method, the most critical step is the estimation of wind speed data, which requires historical wind speed data and a wind speed prediction model [8]. A well-designed wind speed prediction model in the Monte Carlo simulation can lead to very reliable results coming from large amount calculation time on sequential simulation. The analytical solutions proposed by some authors use various interesting approaches. The Multi-state models [9, 10, 11] make use of wind turbine power output curve and wind speeds to generate partial power output states of wind turbine generators, which represent various energy levels indicating the correlation between fluctuating characteristics of wind speed and wind turbine power output. The number of these states is determined by characteristics of wind data and required accuracy. Load adjustment approach [12] accounts for fluctuating energy by eliminating the power output from the utility load firstly, and then uses the adjusted load values not including wind energy to calculate the reliability indices.In this paper, we present the principal modules of the simulator and, using a case study of a hybrid system, we demonstrate some of the benefits that result from easily understanding the effects of the designer's modifications to these complex dynamic systems. In these systems, the voltage and the frequency are controlled by the diesel generator. The wind speed varies with time and so does the station load. Therefore, we regard the diesel generator as a controlled energy source, whereas the wind is an uncontrolled energy source and the station load is an uncontrolled energy sink. The difference between the power consumed by the station load and the power generated by the wind turbine is balanced by the diesel generator.

The following schematic diagram represents the basic wind-diesel hybrid energy system:

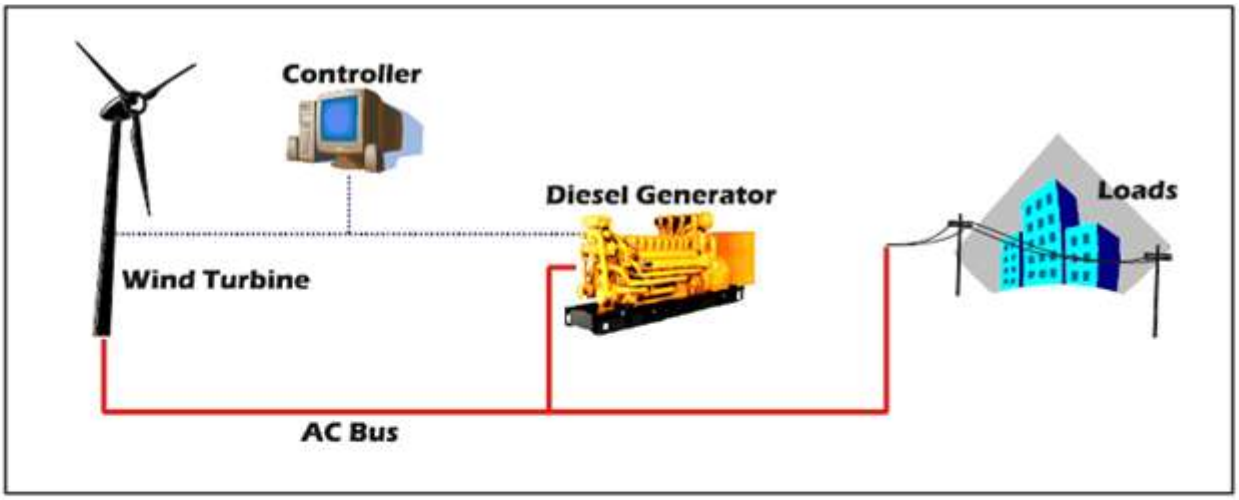


Figure: 1 Basic wind-Diesel hybrid system.

This paper gives the design idea of wind/Diesel hybrid energy system. Based on the energy consumption of mobile base station and the availability of renewable energy sources, it was decided to implement an innovative stand alone Hybrid Energy System combining small wind turbine and existing diesel generators.

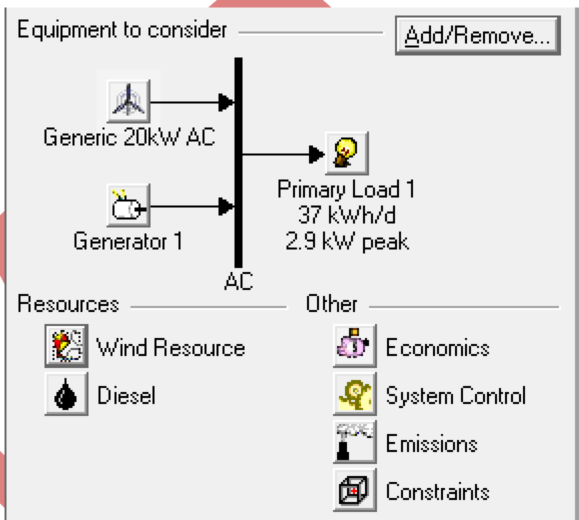


Figure 2. Schematic diagram of Hybrid system for mobile telephony base station.

National Renewable Energy Laboratory (NREL)'s, Hybrid Optimization Model for Electric Renewable (HOMER version 2.19) [14] has been used as the sizing and optimization software tool [15]. It contains a number of energy component models and evaluates suitable technology options based on cost and availability of resources. In this paper the system sizing [13] is carried out using HOMER-optimization and simulation software tool. Analysis with HOMER requires information on resources, economic constraints, and control methods. It also requires inputs on component types, their numbers, costs, efficiency, longevity, etc. Sensitivity analysis could be done with variables having a range of values instead of a specific number.

2. Why Wind/Diesel hybrid system:

The advantage of hybrid power systems is the combination of the continuously available diesel power and locally available, pollution-free wind energy. With the hybrid power system, the annual diesel fuel consumption can be reduced and at the same time, the level of pollution can be minimized. A proper control strategy has to be developed to take full advantage of the wind energy during the periods of time it is available and to minimize diesel fuel consumption. Therefore, a proper control system has to be designed, subject to the specific constraints for a particular application. It has to maintain power quality, measured by the quality of electrical performance, i.e., both the voltage and the frequency have to be properly controlled. This results in a need for a simulation study of each new system to confirm that a control strategy results in desired system performance.

3. Renewable energy resources for hybrid system

The availability of renewable energy resources at mobile base station sites is an important factor to develop the hybrid system. These energy sources are intermittent and naturally available; due to this factor our first choice to power the mobile base station will be renewable energy sources such as wind or solar or hydro etc. Weather data are important factor for pre-feasibility study [16-17] of renewable hybrid energy system for any particular site. Here the Wind energy resources data are taken from RGPV BHOPAL of the year 2011, (Longitude 77^{o}.35'and Latitude 23^{o}.28') and shown in Table 1. In Bhopal wind speed is an average:

Table 1. Weather data for the site

Month	**Wind Velocity m/s**
January	4.300
February	4.567
March	4.789
April	5.321
May	5.732
June	6.131
July	6.431
August	6.110
September	5.910
October	5.230
November	4.831
December	4.321
Average	5.310

Wind energy resource:

An average wind dataset of one year for Bhopal ware collected from RGPV, Bhopal. This is an average of one year and indicates that monthly average wind speed and shown in Figure 3. From the above given data, wind speed probability function and average monthly wind speed throughout the year is shown in Figure 3.

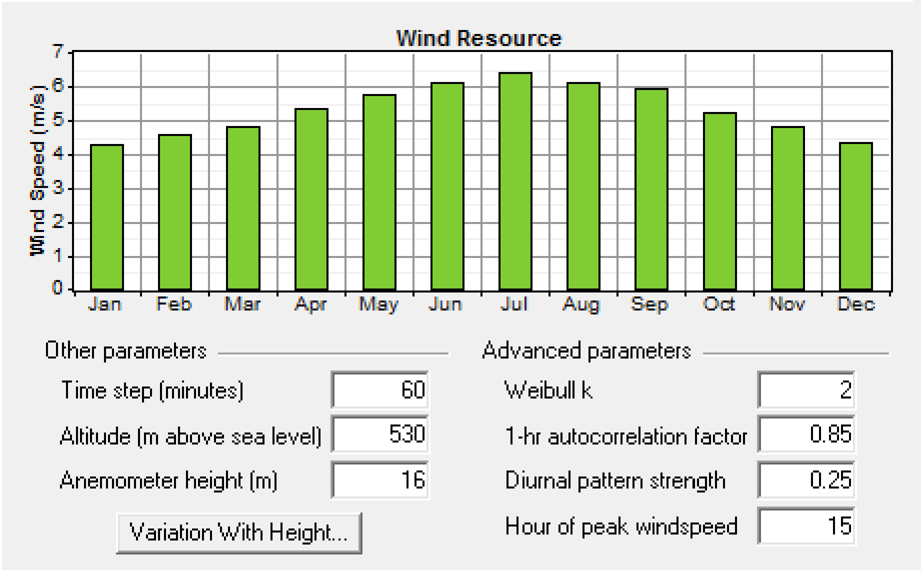


Figure: 3 wind speed probability function and average monthly wind speed

The autocorrelation factor (randomness in wind speed) is found to be 0.85. The diurnal pattern strength (Wind speed variation over a day) is 0.25 and the hours of peak wind speed is 15. Average wind speed in the summer season is slightly higher than the winter season as shown in Figure 3(i).The power output throughout the year according to wind speed is shown in Figure 3 (ii).

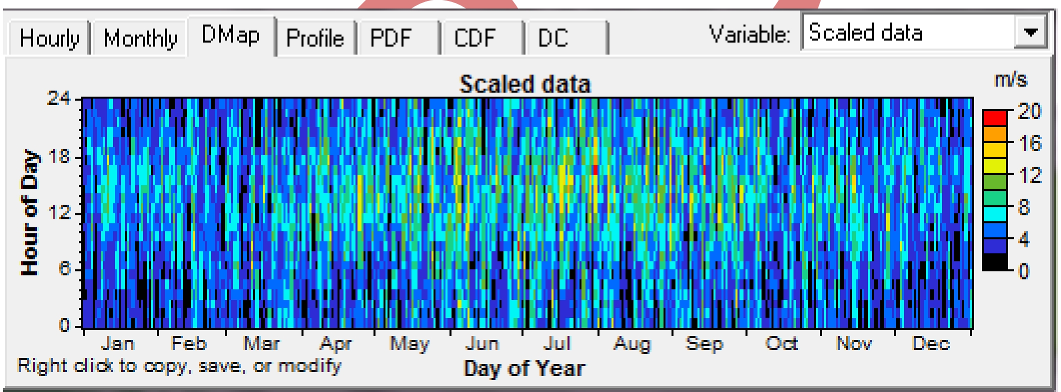


Figure: 3 (i) wind speed probability function and average monthly wind speed

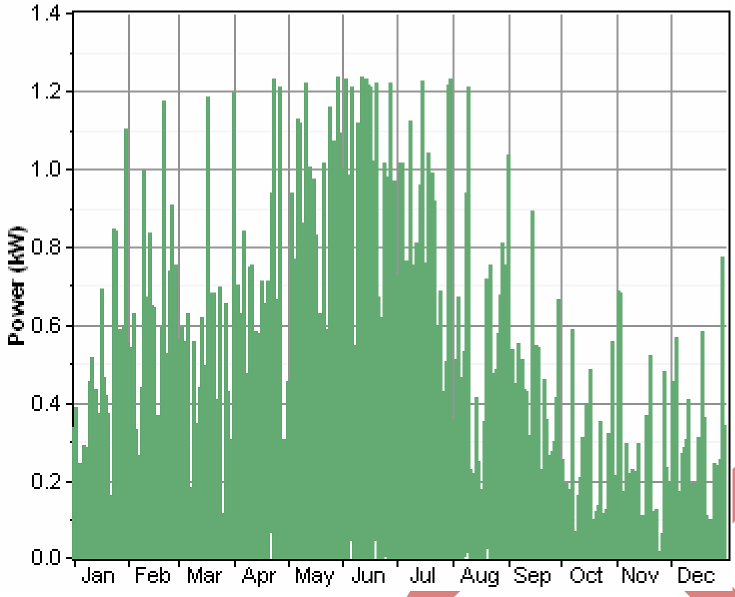


Figure: 3 (ii) wind speed probability function and average monthly wind speed.

4. Load pattern for mobile telephony base station:

Cellular telephone service is a rapidly expanding and very competitive business world over including developed and developing countries like India, America, European countries etc. Right now there are 55,000 different type base stations for telecom sector in India and most of them running on diesel generators. But diesel generators are often expensive to run and more than one diesel generator are installed for uninterrupted service. The different types of telecom base station are used according to the technological advancement in telecommunication sector.

Recently the GSM 2/2/2 (2nd Generation Global System Mobile telephony base station) are used in all over the world. For pre-feasibility study of designing the solar wind hybrid system considered the 2nd Generation GSM base station. In this present study consider the power requirements for GSM telephony base station site are about average of 1.54kW. The load demand is approximate 36.9 kWh/d and 2.95 kW peak, as shown in figure: 4.

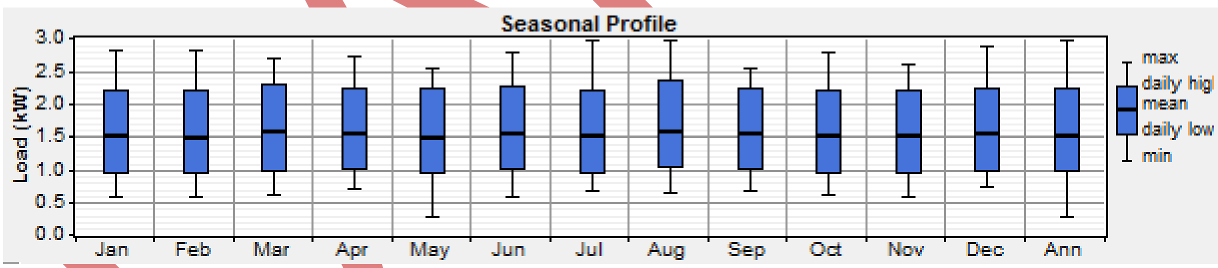


Figure: 4 monthly load distributions throughout the year.

5. Hybrid energy system components:

The proposed hybrid system consists of the following:

4.1) *A 20 kW AC Wind turbine:*

A Generic 20 kW AC Wind electric generator is taken for this system. It converts wind energy into electrical energy. Availability of energy from the wind turbine depends greatly on wind variations. Therefore, wind turbine rating is generally much higher compared to the average electrical load. It has a rated capacity of 20kW AC. As outputs Cost of one unit is considered to be $36167, while replacement and maintenance costs are taken as $15000 and $100/year respectively. The cost analysis is shown in Figure 5 (i). The power curves of wind turbine are shown in Figure 5 (ii). To allow the simulation program find an optimum solution, lifetime of a turbine is taken to be 15 years.

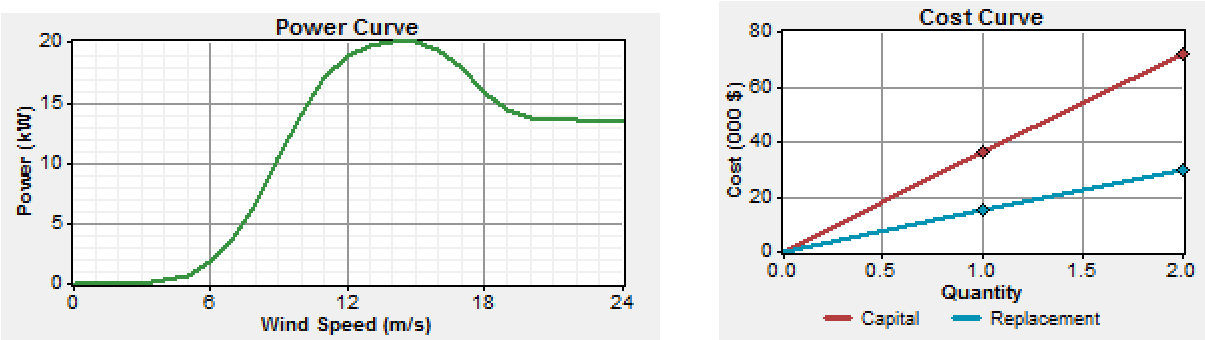


Figure 5. A 20 kW AC Wind Generator. (i) Power curve, and (ii) cost curve

4.2) *Diesel generator:*

The fuel consumption per year is approximate 5000 Litter for 5kW Diesel Generator. The 5 kW diesel generator capital cost, replacement cost, operation-maintenance cost are 2803$, 1000$, 0.002$. At present, diesel price is around 0.938$/L and for a very remote location this could increase up to 1$/L. Sizes to be consider for obtaining optimal hybrid system is 5kW .This analysis shown in Figure 6.

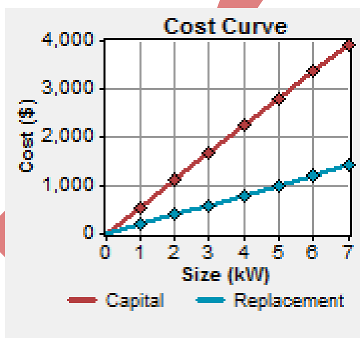


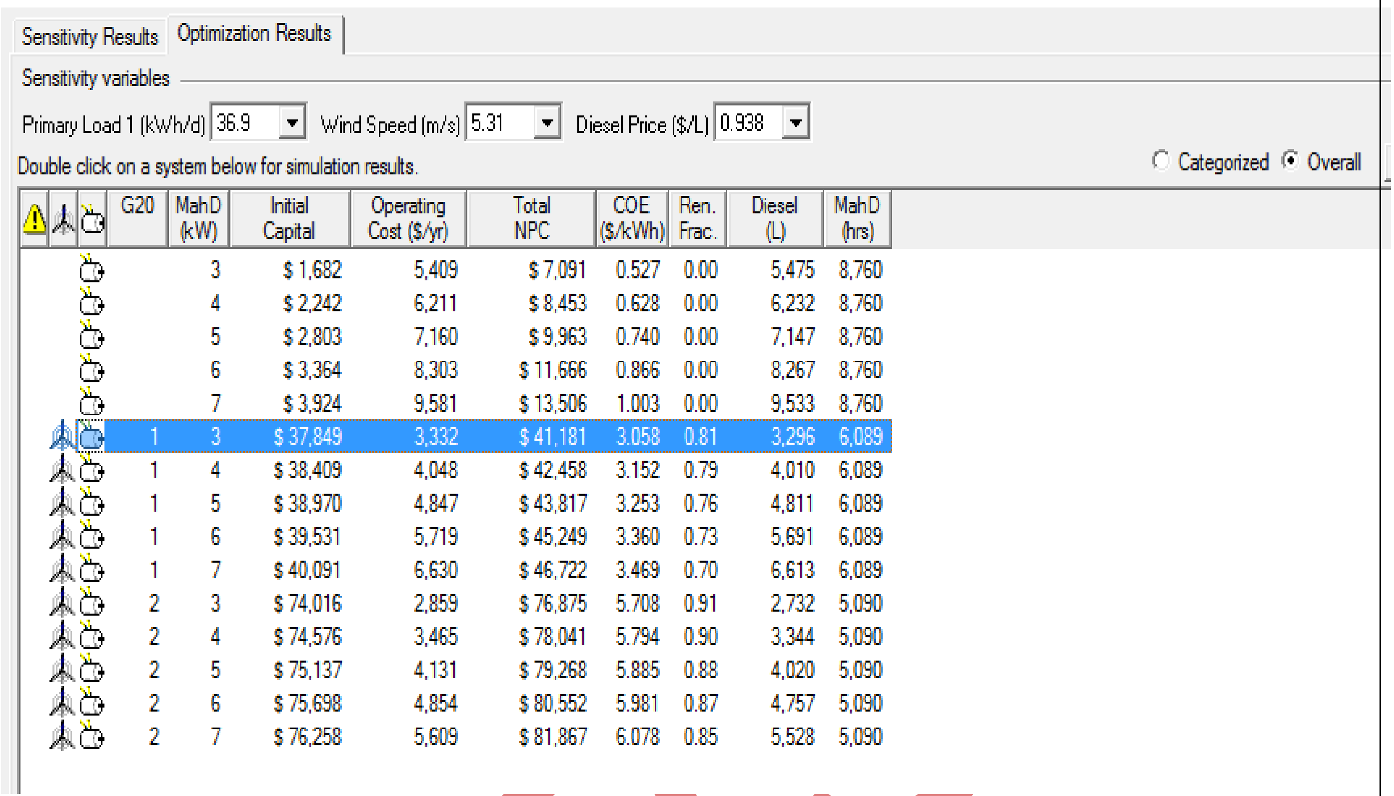
Figure: 6 Cost Curve of Diesel Generator.

6. Results and Discussion:

The above proposed hybrid system supply the power to the mobile telephony base station continuously throughout the year. For the analysis of this hybrid system consider two sensitivity variables (wind speed and fuel cost). For each of the sensitivity values simulate all the systems in their respective. An hourly time series simulation for every possible system type and configuration is done for a 1-year period. An optimal system is defined as a solution for hybrid system configuration that is capable of meeting the load demand of telephony base station.

6.1) *Optimization results:*

From the simulation results the installation of wind diesel hybrid system configuration for various locations are most suitable power solutions for telecom base station network in Indian sites. Considering present cost analysis of a Wind/Diesel hybrid system is suitable for stand-alone loads around Bhopal. From the optimization results the best optimal combination of energy system components are one Generic 20 kW AC Wind Generator and 5 kW Diesel Generator. Total net present cost (NPC), Capital cost and cost of energy (COE) for such a system is $41,181, $37,849 and 3.058$/kWh, respectively for one year. The detailed optimization results are shown in Figure 7.



G20	MahD (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Diesel (L)	MahD (hrs)
	3	$ 1,682	5,409	$ 7,091	0.527	0.00	5,475	8,760
	4	$ 2,242	6,211	$ 8,453	0.628	0.00	6,232	8,760
	5	$ 2,803	7,160	$ 9,963	0.740	0.00	7,147	8,760
	6	$ 3,364	8,303	$ 11,666	0.866	0.00	8,267	8,760
	7	$ 3,924	9,581	$ 13,506	1.003	0.00	9,533	8,760
1	3	$ 37,849	3,332	$ 41,181	3.058	0.81	3,296	6,089
1	4	$ 38,409	4,048	$ 42,458	3.152	0.79	4,010	6,089
1	5	$ 38,970	4,847	$ 43,817	3.253	0.76	4,811	6,089
1	6	$ 39,531	5,719	$ 45,249	3.360	0.73	5,691	6,089
1	7	$ 40,091	6,630	$ 46,722	3.469	0.70	6,613	6,089
2	3	$ 74,016	2,859	$ 76,875	5.708	0.91	2,732	5,090
2	4	$ 74,576	3,465	$ 78,041	5.794	0.90	3,344	5,090
2	5	$ 75,137	4,131	$ 79,268	5.885	0.88	4,020	5,090
2	6	$ 75,698	4,854	$ 80,552	5.981	0.87	4,757	5,090
2	7	$ 76,258	5,609	$ 81,867	6.078	0.85	5,528	5,090

Figure 7. Optimization results of hybrid energy system for mobile telephony base station.

6.2) *Simulation results:*

In this simulation results eliminates all infeasible combinations and ranks the feasible systems according to increasing net present cost. It also allows a number of parameters to be displayed against the sensitivity variables for identifying an optimal system type. The Monthly Average Electricity Production of Hybrid Energy System for mobile telephony base station is shown in Figure 8. In this system the total production of electrical energy is fulfill the load demand by the combination of 81% by Wind and rest of 19% by Generator.

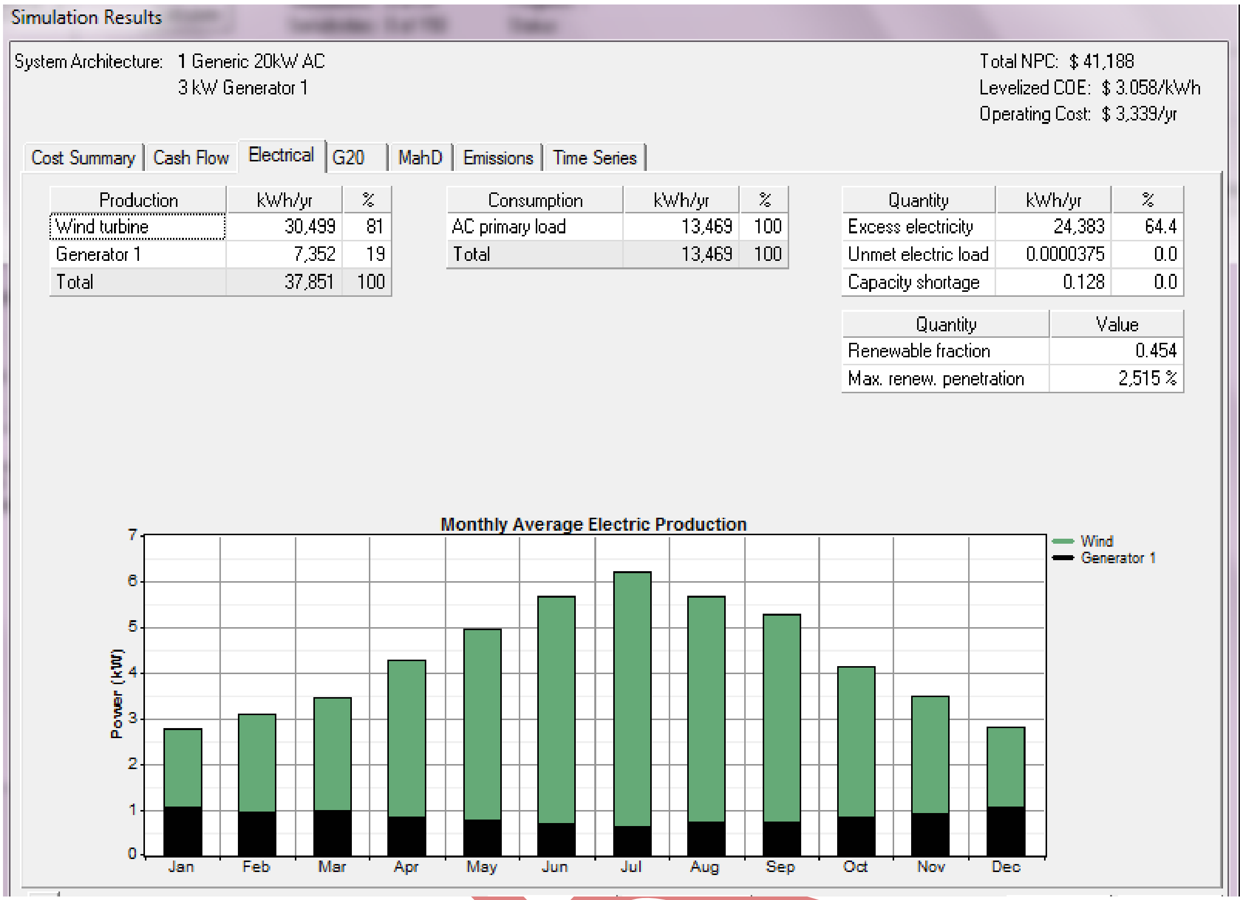


Figure8. Annual electricity production by this hybrid system.

7. Conclusion:

In India more than 1.2 billion peoples are mobile user. To provide better network services mobile operator installed new mobile base stations. Power is main issue for remote areas base station, because grid extension is not feasible. In these sites the above proposed renewable base hybrid system is most efficient solution. These solutions of power supply to the telecom base station are cost effective and available throughout the year. The circumstance of each sites are studied in order to decide the feasible combination of alternative energy resources. Alternate power solutions are not commonly used in mobile telecommunication system today but are actively evaluated for remote and isolated areas over worldwide.

With the help of above pre-feasibility study the wind/diesel hybrid energy system is most efficient power solution for mobile base station in Indian sites over conventional diesel generator**.** Although the net present cost is high but the running and maintenance cost are low as compared to the diesel generator power solution. It's payback time is around 8 years.

The fuel consumption is also reduced to approximate 82% with increasing oil prices, payback times on the investment to hybrid wind/diesel powered base station sites are continuously decreasing. Considering operating cost and maintenance cost, an autonomous site powered by wind/diesel hybrid system pay-off after 4-5 years in a good windy location. The Base stations powered by the wind/diesel hybrid energy system, with diesel backup are proving to be the most environmentally friendly and cost-effective solutions for many challenging sites. Due to powering the base station by hybrid renewable energy system, it will reduce the carbon and other harmful gases emission is about 90% in environments.

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